Relationships between felt intensity and instrumental ground motion measures for New Madrid ShakeMaps, NEHRP Award 05HQGR0039

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Nontechnical Summary

ShakeMap is a computer-generated map of earthquake ground shaking and felt effects, including damage, which is produced within minutes of the occurrence of a felt earthquake. ShakeMap is a critical tool to mitigating damage in the immediate aftermath of a significant earthquake, and also provides public information. ShakeMaps rely on relationships that translate instrumentally recorded ground motions into predictions of felt effects and damage. These relationships are developed from observations linking recorded ground motion to Modified Mercalli Intensity from past earthquakes. The current project is developing the relationships between instrumental ground motions and felt intensity that are needed to make reliable ShakeMaps for the New Madrid region of the central United States.

Introduction

ShakeMap programs that provide information on ground-shaking effects in near-real-time were first developed for southern California (Wald et al., 1999, Seism. Res. L.) and are now being implemented in many regions across the United States, including the New Madrid seismic zone in the Central United States. ShakeMaps are a critical tool to mitigating and preventing further damage in the immediate aftermath of a significant earthquake, as they allow emergency response personnel and operators of critical facilities to prioritize their responses and take appropriate action. ShakeMaps also perform a valuable public information function in the immediate aftermath of small to moderate earthquakes. ShakeMaps rely on relationships that translate instrumentally recorded ground motions into predictions of felt effects and damage. These relationships are developed from observations linking recorded ground motion to Modified Mercalli Intensity from past earthquakes. At present, ShakeMaps in the Central United States (CUS) must rely on relationships developed from earthquakes in California. However, recent studies have shown that these relationships underpredict intensity for earthquakes in the northeastern U.S. and southeastern Canada. Thus region-specific relations are required. This is particularly important in the CUS, where the combination of thick sediments of the New Madrid region and efficient propagation of high frequency radiation across large distances form a unique environment that may lead to a unique relationship between ground motion and felt intensity. Without region-specific relations between instrumental ground motions and MMI, reliable ShakeMaps for the New Madrid seismic zone cannot be developed.

This study is developing the empirical relationships between instrumental ground motions and felt intensity that are needed to make reliable ShakeMaps for the CUS region. In contrast to California, events that generate strong shaking are rare in the CUS. For CUS applications, it is important to create reliable intensity ShakeMaps for the more frequent small-to-moderate events that may be widely felt, but cause little to no damage (in addition to our interest in the larger

events). Such maps are useful for public information purposes, particularly to operators of critical facilities that must provide timely information on all felt events. Having reliable maps for the frequent small events is also critical to building credibility, so that ShakeMaps for larger events, when they occur, will be effectively utilized. ShakeMaps for the CUS must cover a wide range of intensities and magnitudes, from frequent small-to-moderate events to large rare earthquakes.

The instrumental database for this study is derived from readily-available ground-motion data (primarily broadband) that have been recorded for felt earthquakes in the New Madrid region in the last few years. These data, shown in Figure 1, allow relationships between instrumental ground motions and intensity to be developed for low intensity levels. The relations must be extended to higher intensity levels and larger magnitude earthquakes by using inferred ground motions from historical earthquakes that have well-documented felt effects. The low-level intensity data aid in the validation/calibration of relations used to infer the historical ground motions. By careful combination of actual observations from moderate earthquakes, and inferred ground motions from larger historical events, appropriate relations between MMI and instrumental ground motion relations are being developed for ShakeMap applications in the Central United States.

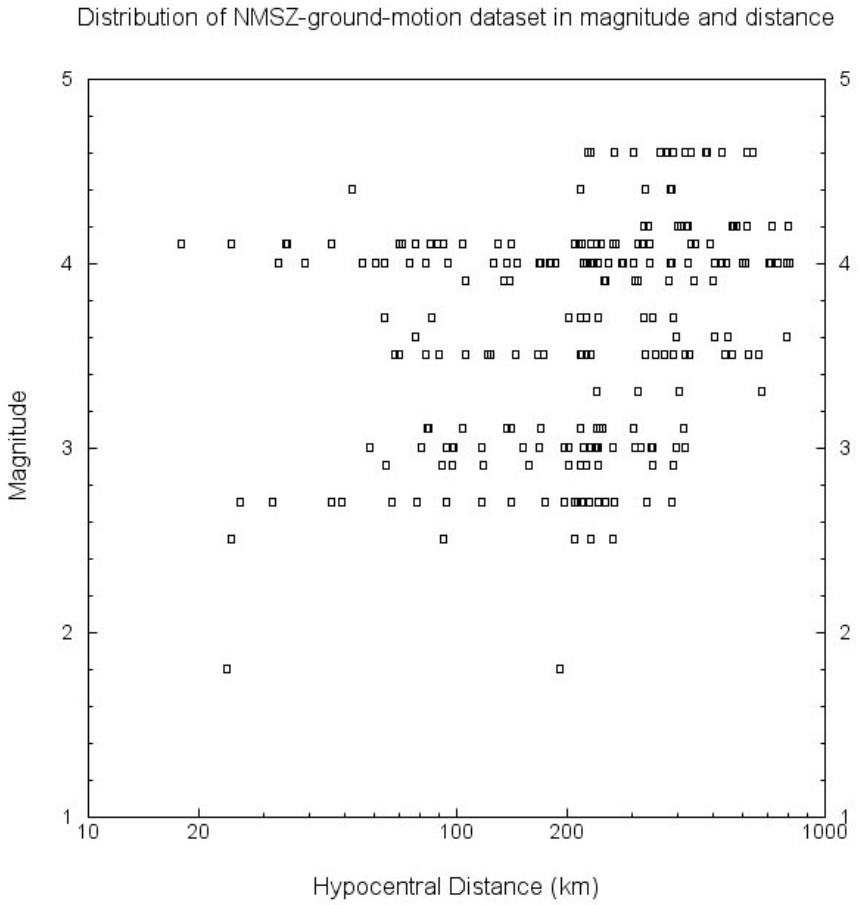

Figure 1 – Distribution of study database in magnitude and distance. Points show magnitude-distance combinations for which both instrumental ground-motion data and intensity reports are available (CUS region).

Preliminary Results

We have compared the relationship between felt intensity and ground motion amplitude that is observed in the New Madrid Seismic Zone (NMSZ) to that observed in California. In California, relationships were developed between MMI (as obtained from the classical postal survey method) and response spectral acceleration (PSA) based on strong-motion databases (Atkinson and Sonley, 2000; Wald et al., 1999). These relationships are robust at higher intensity levels, for which both the strong-motion and MMI databases are good, but are not well-constrained at low intensity levels. We therefore augmented the California data at low intensity levels by using ShakeMap and Did You Feel It? (DYFI) data from California (downloaded from U.S.G.S. websites). Figure 2 compares instrumental PSA levels (for 1Hz and 3.3 Hz) corresponding to each Modified Mercalli intensity (MMI) level in California, based on both ShakeMap/DYFI and strong-motion/classical MMI sources (Atkinson and Sonley, 2000), to the ShakeMap/DYFI data compiled for the New Madrid region. Data for eastern North America (Kaka and Atkinson) are also plotted. It is apparent that the California data from ShakeMap (turquoise symbols) are not consistent with the California strong-motion data (blue symbols) at low intensities, but become consistent at MMI≥5. This is an important observation. It likely results at least in part from biases in the strong-motion database, due to triggering/non-triggering effects at low intensity levels. For MMI<5, the ShakeMap data for California are considered more reliable. There may also be a magnitude effect on observed intensity, as the ShakeMap data for California tend to be from lower magnitudes. Note that neither source is likely to be reliable at the lowest intensity levels (MMI<3). The New Madrid ShakeMap data appear to be reasonably consistent with the California ShakeMap data, although there is a tendency towards higher ground motions in the NMSZ for the same MMI. Both the NMSZ and California exhibit higher ground motions for the same MMI than is seen in eastern North America (black symbols; Kaka and Atkinson). The reasons for these differences are currently being investigated. It appears they may be due to the fact that intensity depends not just on ground-motion amplitude, but also on distance and magnitude. The distribution of data in distance and magnitude, for the same intensity, is different in the various regions.

The final report, to be submitted early in 2006, will provide the complete results, completed interpretation, and recommendation of relationships between intensity and ground motion parameters for use in ShakeMaps in the New Madrid region. At the conclusion of the study, the compiled MMI and ground-motion database for the New Madrid region will be available in an excel spreadsheet format for the use of other investigators. It can be obtained by email request to gma@connect.carleton.ca.

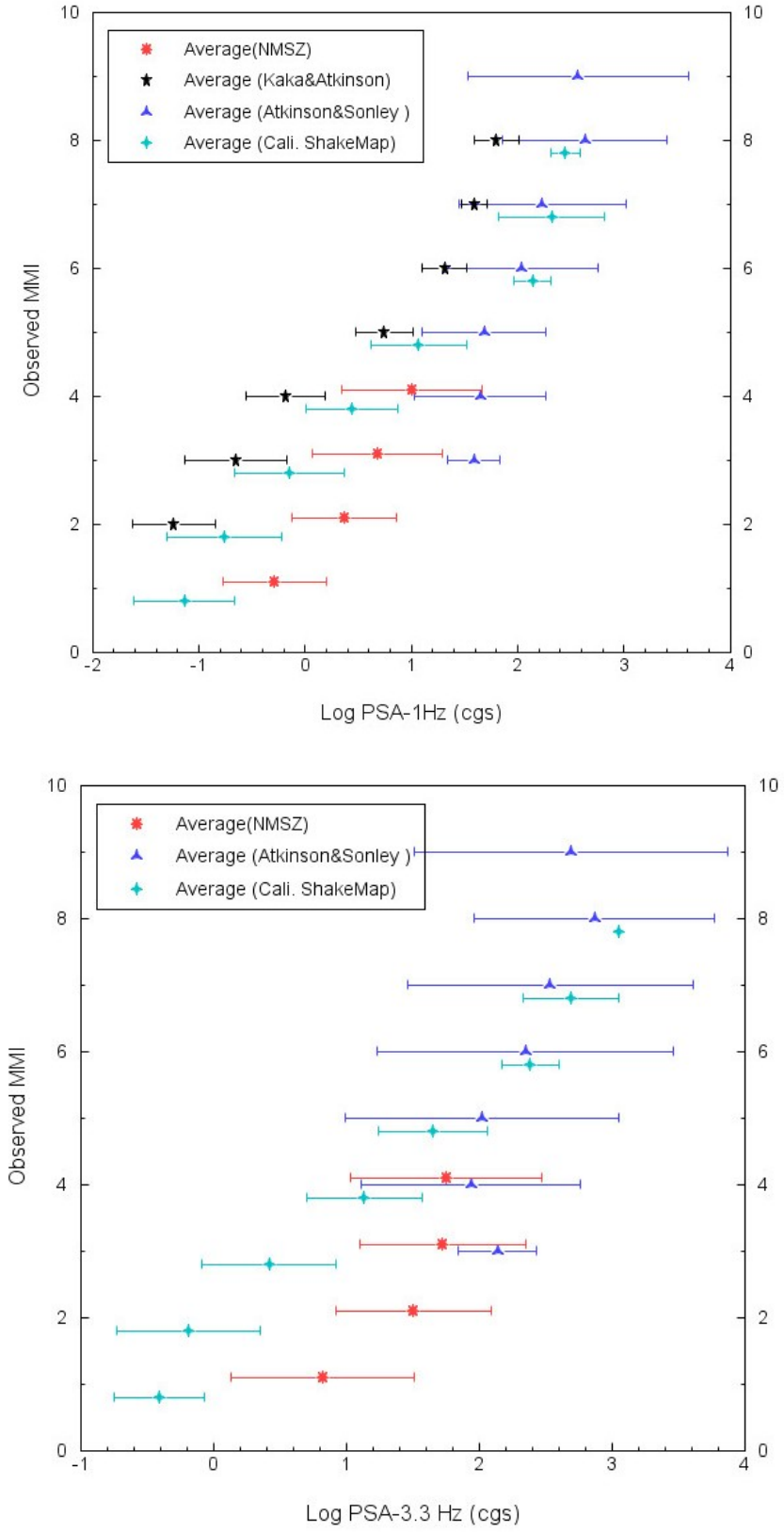

Figure 2 – Comparison of correlations between felt intensity and instrumental PSA at 1 Hz (upper) and 3.3 Hz (lower). Blue and turquoise symbols show data from strong-motion studies and ShakeMap, respectively, for California. Red symbols are observations from ShakeMap in the New Madrid region. Black symbols (top plot only) are observations from eastern North America (Kaka and Atkinson). All data are horizontal component. Symbols show mean, with error bars indicating standard deviation.